Optical Link ASICs for LHC Upgrades

The Ohio State University

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Outline

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- PIN receiver/decoder chip
- Clock multiplier
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Introduction

● 1\textsuperscript{st} phase of LHC upgrade is planned for 2014:
  ◆ 3 times increase in luminosity to $3 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
  ◆ expect significant degradation in the ATLAS pixel detector
  ⇒ add an insertable barrel layer (IBL) at radius of 3.5 cm

● Possible upgrade for on-detector optical readout system for the IBL:
  ◆ add new functionalities to correct for deficiencies in current system
  ◆ upgrade current optical chips to run at higher speed
  ◆ some of the development could be of interest to SLHC upgrade
  ◆ use 130 nm CMOS 8RF process
  ◆ prototype chips received/irradiated in July/August 2008
  ⇒ results will be presented below
Opto-Chips

640 Mb/s VCSEL driver

3.2 Gb/s VCSEL driver

640 MHz clock multipliers
(4 x 160 and 16 x 40 MHz)

PIN receiver/decoder
(40, 160, 320 Mb/s)

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2.6 mm x 1.5 mm
Testing the 130 nm Opto-Chips

- chips were tested in the lab at Ohio State University
- chips were irradiated with 24 GeV protons to SLHC dose at CERN
  - 8 VCSEL drivers: 4 “slow” + 4 “fast”
  - 4 PIN receivers/decoders (purely electrical testing)
  - 4 PIN receivers/decoders coupled to PIN
  - 4 clock multipliers
  - long cables limited testing of drivers/receivers to 40 Mb/s
  - special designed card allows testing of clock multiplier at 640 MHz
VCSEL Driver Chip

- Slow VDC
  - 640 Mb/s
  - ~ 14 mA max

- Fast VDC
  - 640 Mb/s
  - ~ 9 mA max

- Fast VDC
  - 3.2 Gb/s

- both slow/fast chips are working
- LVDS receiver/VCSEL driver work at high speed
  - BER < 10^{-13} @ 4 Gb/s using 10 Gb/s AOC VCSEL
VDC Irradiation

- VDC driving 25 Ω with constant control current (Iset)
- drive current decreases with radiation for constant Iset
  - driver circuit fabricated with thick oxide process
Unirradiated vs. Irradiated VDC

- VDC driving 2.5 Gb/s Optowell VCSEL
- Possible to obtain similar eye diagram by adjusting control currents
  - radiation induced changes in control current circuitry
Threshold Shift in Irradiated PMOS

- Have access to two transistors for characterization
  - simulation with 300 mV threshold shift reproduces observed V vs. I
  - PMOS and NMOS have different threshold voltage shifts
  - will use only PMOS in the current mirror
Receiver/Decoder Chip

- Designed to operate at 40, 160, and 320 Mb/s
  - achieve only 250 Mb/s due to lack of time for design optimization before submission
  - no significant degradation up to SLHC dose
Low Voltage Differential Driver

- output has fast rise and fall times
- output has proper amplitude and baseline
  - small clock jitter, e.g. < 50 ps (1%) @ 160 MHz
  - no significant degradation up to SLHC dose
Single Event Upset

- Single event upset (SEU) measured with receiver/decoder coupled to a Taiwan PIN for 40 Mb/s operation
  - SEU rate much higher for chip coupled to PIN as expected
  - no significant degradation with radiation observed

![Graph showing SEU rate](image)

Chip only

![Graph showing SEU rate](image)

Chip coupled to PIN Diode

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Clock Multiplier

- clock multiplier needed to serialize high speed data
- both 4 x 160 MHz and 16 x 40 MHz clock multipliers work
  - use of recovered clock as input does not increase jitter
Clock Multiplier

- SEU in PIN coupled to data/clock decoder disturbed the input clock
  - Observation confirmed with simulation
- Output clock takes \( \sim 3 \mu s \) to recover
- Two of the four chips lost lock during irradiation
  - Need power cycling to resume operation at 640 MHz
- No change in current consumption

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![Graph showing current consumption vs. dose](image-url)

![Graph showing transient response](image-url)
Summary

● first 130 nm submission mostly successful
● no significant degradation up to 73 Mrad
  ◆ observe threshold shift in thick oxide transistors
● aim for next iteration in autumn 2009 with new functionalities
  ■ individual control of VCSEL currents
  ■ redundancy: ability to bypass a bad VCSEL/PIN channel